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Synthesis of nano-quasicrystalline decagonal phase

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Abstract Al-Co-Ni system exhibits the existence of a stable decagonal phase with various degrees of order in periodic and quasiperiodic planes. Now it is a routine technique to grow micron to cm size rods of the decagonal phase by slow cooling technique. There are attempts to develop nano scale microstructure by various non-equilibrium processing techniques. The aim of the present investigation is to employ mechanical milling (MM) technique for the synthesis of the nano decagonals phases. The alloy ingots have been prepared by melting the constituent pure metals in the induction furnace, and then crushed to around 200 mesh size, as a starting material in the attritor. The milling was performed at 400 rpm under hexane medium with a ball charge ratio as 20 : 1. During the course of milling, the disordering has been noticed from the broadening of the peaks and lowering of the peak height in the X-ray diffraction patterns. Milled powder after 40 h showed the diffraction peaks confirming the evolution of nano-D phase. The size aspects and the phase constituents has further been confirmed by the transmission electron microscopic investigation. The composition of the as-cast ingot and the milled powder has been analyzed by EDX.

Keywords · Quasicrystal, decagonal phase, mechanical milling, disordering.

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1. Introduction

After the initial discovery of icosahedral quasicrystals in a rapidly cooled Al-Mn alloy by Shechtman *et al* [1], many quasicrystalline phases exhibiting five, eight, ten and twelve fold rotational symmetries have been observed in various systems [2,3]. Among these, the stable icasahedral and for decagonal quasicrystal (DQC) are of special interest. Icosahedral quasicrystal are aperiodic in all three direction, in real space whereas DQC are periodic along one axis and aperiodic in the plane perpendicular to this direction. The thermodynamically stable decagonal quasicrystal with remarkable structural perfection in the ternary Al-Co-Ni system was reported by Tsai *et al* [4] by rapid solidification.

Nanocrystalline solids in which the grain size is in the nanometre range, often have interesting properties [5]. Nanocrystalline materials can be produced by several ways, such as gas condensation [6], spray conversion processing [7], sputtering, physical vapour deposition [8], electron deposition [9], mechanical milling (MM) [10–12] *etc*. Mechanical milling technique is to produce alloys with nano-structure at or near to room temperature. The formation of nanoquasicrystalline phase by MM/MA has been reported in a number of Al and Ti based system [13,14]. In the present investigation, we have used the pre-alloyed quasicrystalline material for evaluation of nano-quasicrystal by mechanical milling. The aim of the present paper is to report the formation of nano-decagonal phase of $Al_{70}Co_{15}Ni_{15}$ by mechanical milling.

2. Experimental details

The alloy of $Al_{70}Co_{15}Ni_{15}$ with a purity Al 99.94%, Co 99.96%, Ni 99.91% was prepared by melting in an induction furnace, in the presence of dry organ atmosphere. The ingots formed were remelted several times to ensure homogeneity. The as-cast ingot was crushed to particles less than 0.2 mm in size and placed in the attritor ball mill with a ball to powder weight ratio of 20 : 1. Attritor has a cylindrical stainless steel tank of inner diameter 13 cm. The speed off the mill was maintained at 400 rpm. The milling operation was conducted from 5 to 40 h using hexane as process control agent. Structural evaluation of powders during milling was examined by X-ray diffraction (XRD) employing CuKα radiation (λ = 1.5402 A) at 30 kV and 20 mA. Instrumental broadening was examined using standard Si chip. Transmission electron microscopy (TEM) was performed employing a Philips

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